The Finite Element Analysis of Plastic Deformation Behaviour of If-Steel during Equal Channel Angular Pressing through 90^{o} Die Angle

Malothu Ramulu, Arakanti Krishnaiah

***Abstract*— The Finite Element Analysis (FEA) of plastic deformation behavior of IF-Steel during Equal Channel Angular Pressing (ECAP) has been studied (with two equal channels intersects at 90^{o}) by using ANSYS software package. The 2-dimensional models were developed using FEA under a plane strain condition to estimate the equivalent plastic strain levels in an IF Steel workpiece after single pass at room temperature during ECAP. It is observed that the precise results were obtained in comparison to the analytical models reported in the literature. It is found from the finite element analysis that the geometry of die, back pressure and friction have great influence on the plastic deformation, where these parameters lead to strain distribution of workpiece becomes inhomogeneous and non- uniform.**

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

I. INTRODUCTION

The processing of nanostructured materials by means of Severe Plastic Deformation (SPD) processes has attracted a great scientific interest, mainly by the advantages of the SPD materials in comparison to other nanostructured materials [1]. Equal Channel Angular Processing (ECAP) is one of the examples of discontinuous process of SPD, which is the most promising to fabricate bulk ultrafine grained (UFG) materials. To date, a number of studies on the significant parameters affecting the plastic deformation behavior during ECAP such as materials properties die design and friction conditions have been conducted using the finite element method (FEA) and experimentally [2-5], which has also been used for analyses on the loading history and the corner gap formation between die and workpiece during ECAP. For those studies, the stress and strain distributions within the workpiece during ECAP were mainly considered. Strain rate was also a significant tool in analysis of plastic deformation, and evaluated the effects of the die geometry on the variation of strain rate during ECAP [6-7]. The plastic deformation behavior of the IF steel during ECAP and the mechanical properties after ECAP processing were simulated [8]. The equivalent strain and non-uniformity of stress-strain distribution of ECAP extruded samples are characterized novelty through the mechanical parameter relating to material property rather than the classical geometry equation [9-10]. The principle of the ECAP method is shown in figure 1 & 2 [11-12].

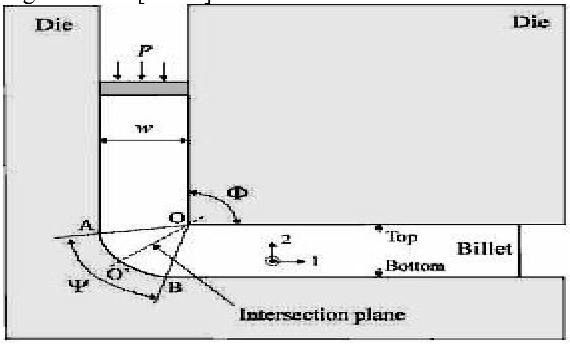

Figure1: ECAE die geometry featuring the ϕ and Outer corner angle ψ [11].

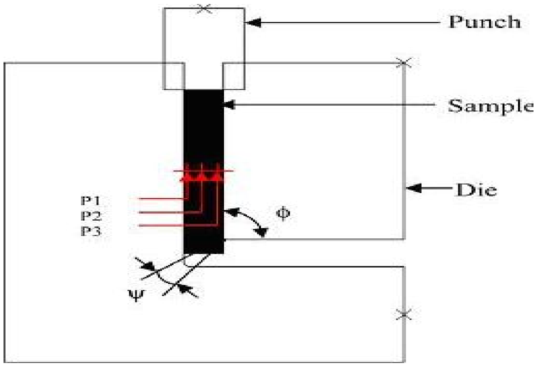

Figure 2: Finite element model of die angle ϕ corner angle ψ [12].

The ECAP is a very interesting method provided that the overall dimensions of the workpiece remains unchanged and the accumulated plastic strains are very high in comparison to the traditional metal forming methods like the rolling and the drawing. So, the understanding of the mechanics of plastic deformation take place during the ECAP is essential to evaluate the microstructure and grain size attained as a function of the processing routes.

In the present work, a quasi-static solution to the ECAP method by the FEA modeling was done using two channels at angle of intersection 90^{o}, considering only single pass of pressing and adopting a plain strain condition. The generalized Coulomb law was assumed in all cases.

FINITE ELEMENT ANALYSIS

The two-dimensional plane strain element (Plane 182) was carried out using the ANSYS package. The material properties used are for If Steel. The workpiece is considered of dimensions 10 mm (width) x 50 mm (height) and unity

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thickness since a plane strain condition is assumed. The stress strain relation is

$$\sigma = 544.96(0.004852+\varepsilon)^{0.235}$$

The material properties are

Table 1 IF Steel Properties	
Young Modulus	195000 Mpa
Poisson ratio	0.29
Yield Stress	186 Mpa

For the contact the elements considered are Target 169 and Contact 172. The workpiece was modelled with four node plane strain elements. The friction coefficient between the die channel (Rigid target surface) and workpiece (Contact surface) are 0.00, 0.05, and 0.10. In order to compare the results with the results previously published [8] the values of friction are taken as 0.00, 0.05 and 0.1.

II. RESULTS AND DISCUSSIONS

Figure 3, 4 and 5 show the extrusion force for unit thickness Vs workpiece displacement for the friction conditions 0.0, 0.05 and 0.1 respectively. It can be observed as expected the increase in the friction coefficient requires higher pressures or punch loads. It can be seen that an increase of extrusion force initially (upto 7.5 mm for zero friction condition) and afterwards decreases in the extrusion force. This is in agreement with the results published by others.

Figure 6, 7 and 8 show the Von Mises stress for the friction conditions 0.0, 0.05 and 0.1 respectively. This is a very important to understand the material behaviour i.e. if the Von Mises Stress exceeds the Ultimate Tensile Stress (UTS), then the material is considered to be at the failure condition.

Figure 3: Extrusion Force Vs Workpiece Displacement

Figure 4: Extrusion Force Vs Workpiece Displacement

Figure 5: Extrusion Force Vs Workpiece Displacement

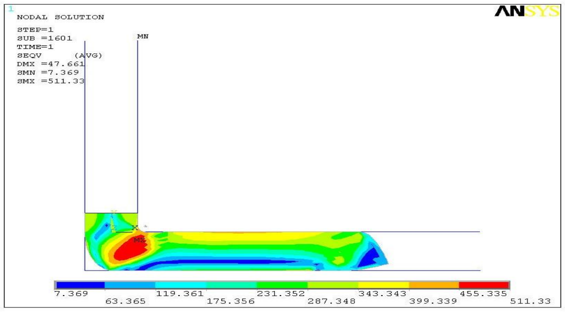

Figure 6: Von Mises Stresses (Friction = 0.0)

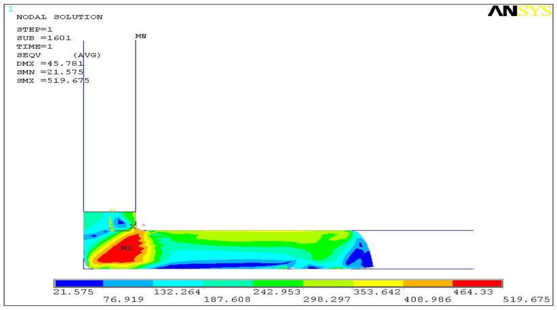

Figure 7: Von Mises Stresses (Friction = 0.05)

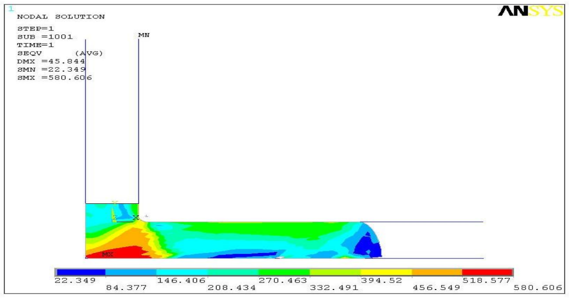

Figure 8: Von Mises Stresses (Friction = 0.1)

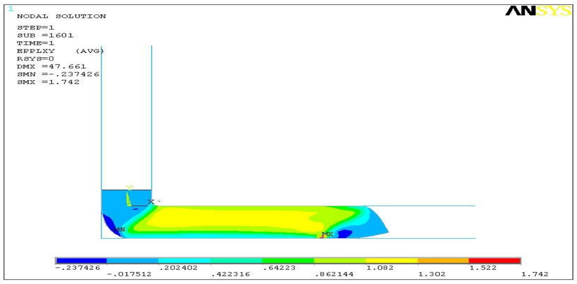

Figure 9: Shear Strain (Friction = 0.0)

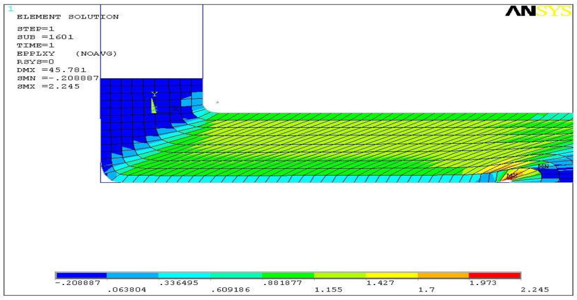

Figure 10: Shear Strain (Friction = 0.05)

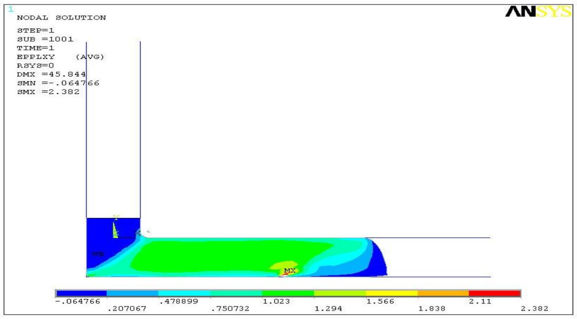

Figure 11: Shear Strain (Friction = 0.1)

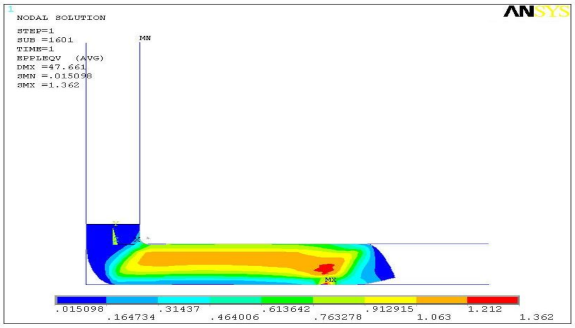

Figure 12: Von Mises Strain (Friction = 0.0)

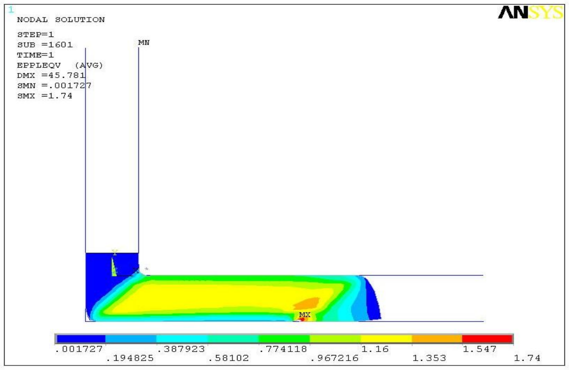

Figure 13: Von Mises Strain (Friction = 0.05)

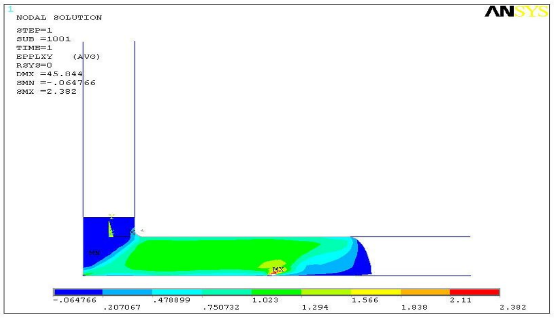

Figure 14: Von Mises Strain (Friction = 0.1)

Figures 9, 10 & 11 give the shear strains for the friction conditions 0.0, 0.05 and 0.1 respectively. Since shear strains give an indication of the plastic deformation undergone and indirectly the microstructure.

Figure 12, 13 and 14 show the Von Mises plastic strain respectively. In this it is observed that the strain reaching high value is highly localized and it is not uniform and same on the total workpiece. A new methodology has to be developed so that the work piece undergoes high plastic strains over the entire workpiece uniformly.

CONCLUSIONS

Plastic deformation behaviour of IF-Steel during ECAP is analyzed under plain strain condition by assuming the generalized Coulomb law in all cases through finite element method using ANSYS package. These were carried out considering strain hardening and frictional contact. It is found that the plastic deformation behaviour of IF Steel during ECAP is localized and the extrusion pressure increases with increasing friction. Also it is found that the deformation is inhomogeneous and non uniform.

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